

# Sediment Accumulation and its Effects on a Mississippi River Oxbow Lake

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**ABSTRACT** / Recent sediment accumulation rates were measured in Moon Lake, a large (10.1 km<sup>2</sup>) Mississippi River oxbow lake in northwestern Mississippi. Moon Lake, which receives channeled inflow from an intensively cultivated soybean, rice, and cotton watershed (166 km<sup>2</sup>) and limited over-

land flow from surrounding lands, exhibited depositional patterns that were associated with (1) points of inflow, (2) flow patterns, and (3) lake morphology. From 1954 to 1965, 70 percent of the lake bottom experienced accumulation rates greater than 2 cm/yr. Accumulation rates exceeded 4 cm/yr in areas of delta formation. Changes in cropping systems during the 1960s, from cotton to soybeans and rice which require less cultivation, resulted in significantly ( $\alpha = 0.01$ ) less sediment accumulation during the period 1965–1982 when 86 percent of the lake averaged less than 2 cm/yr sediment deposition. If current sediment accumulation rates continue, open water habitat in the lake will be reduced by only 3 to 7 percent during the next 50 years.

## Introduction

Instream suspended sediment and bedload materials from erosion are, by volume, the greatest polluting agents in the United States (Fowler and Heady 1981), and the accumulation of these eroded materials is a major problem in the management reservoirs and lakes (Robinson 1971). As sediment fills lakes and reservoirs, it reduces water storage capacity and may adversely affect aquatic ecosystems (Cooper and others 1984). Sediment accumulation is most noticeably detrimental when it fills lakes and reservoirs to the point that fundamental ecotype shifts occur from open water to marshes and the first steps in terrestrial succession.

Moon Lake is a large natural oxbow lake adjacent to the Mississippi River in the alluvium that forms in northwestern Mississippi. The lake was subject to periodic flooding and subsequent flushing by the Mississippi River until closure of the mainline Mississippi River levee in the 1920s. Since settlement began in the 1830s, the percentage of Moon Lake's watershed covered by bottomland hardwoods has declined steadily in favor of intensive cultivation of cotton (*Gossypium hirsutum* L.) and, later, soybeans [*Glycine max* L. Merrill] and rice (*Oryza sativa* L.). Currently, cultivated land occupies over 70 percent of the watershed. Mechanization following World War II promoted draining and clearing of numerous wetlands in the watershed. Local residents and state game and fish per-

sonnel have noted reductions in fisheries productivity and recreational activity in the lake (R. Garavelli, Miss. Dept. Wildlife and Fisheries, Pers. Comm. 1983). The amount and distribution of suspended and deposited sediments are obvious concerns. The purpose of this investigation, as part of a ecological study of Moon Lake, was to determine recent rates and patterns of sediment accumulation within the lake and to predict future changes in the lake based on recent trends.

## Study Area

Moon Lake is a large (10.1 km<sup>2</sup>) oxbow lake in Coahoma County, Mississippi, separated from the Mississippi River by the main river levee. Almost all of its 166 km<sup>2</sup> watershed drains south from Tunica County, Mississippi, through a series of relic oxbow drainages (Fig. 1). Phillips Bayou, the major inflow enters the northern end of Moon Lake and Yazoo Pass, the outflow, breaches the high natural levee on the outside perimeter of the lake about one-third distance around the typical bow pattern (Fig. 1). This outflow pattern leaves the lower two-thirds of the lake past the outflow with very little flow-through movement. For most of its length, the lake maintains the typical river bend thalweg with the shallow inside of the curve deepening to a large main channel (Fig. 2) 7 to 9 m deep. Both northern and southern extremities are quite shallow (<1 m). An island (0.7 km<sup>2</sup>) in the southern half of the lake (Fig. 3) alters lake morphology and fetch.

## Methods

Sixteen sediment profiles at nine cross sections (Fig.

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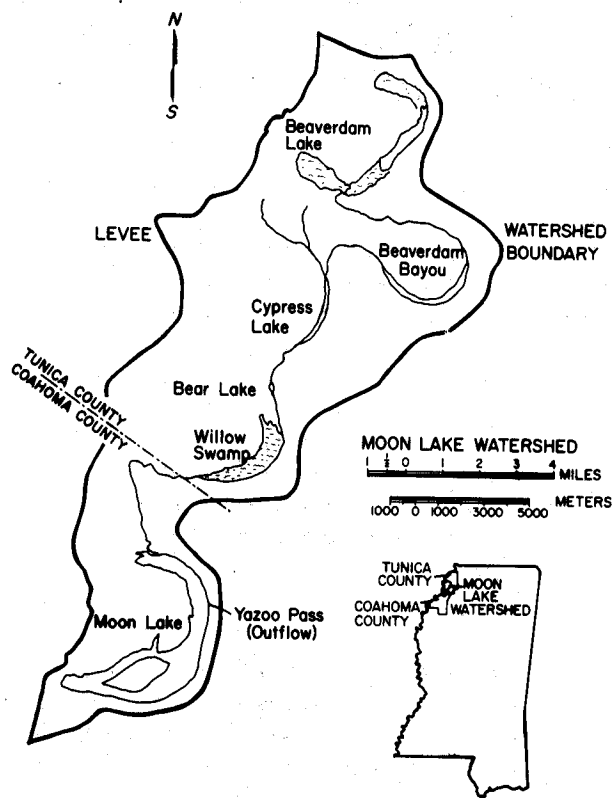


Figure 1. Moon Lake Watershed.

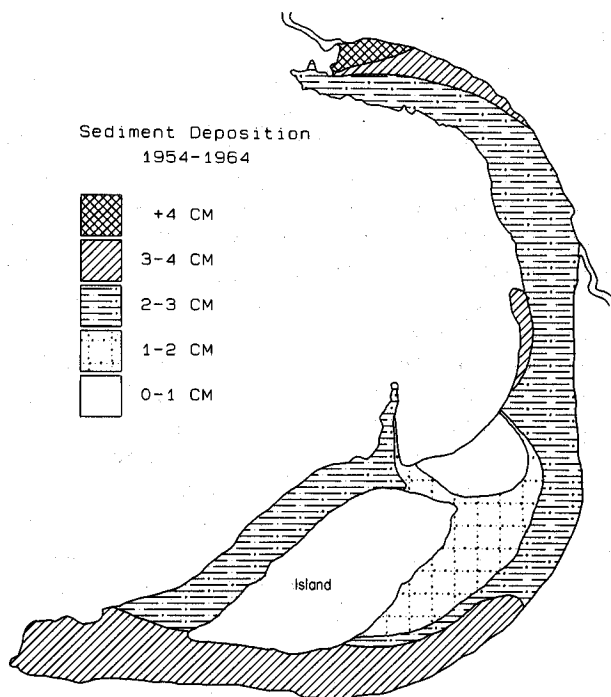


Figure 3. Sediment accumulation patterns per year in Moon Lake from 1954 through 1964.

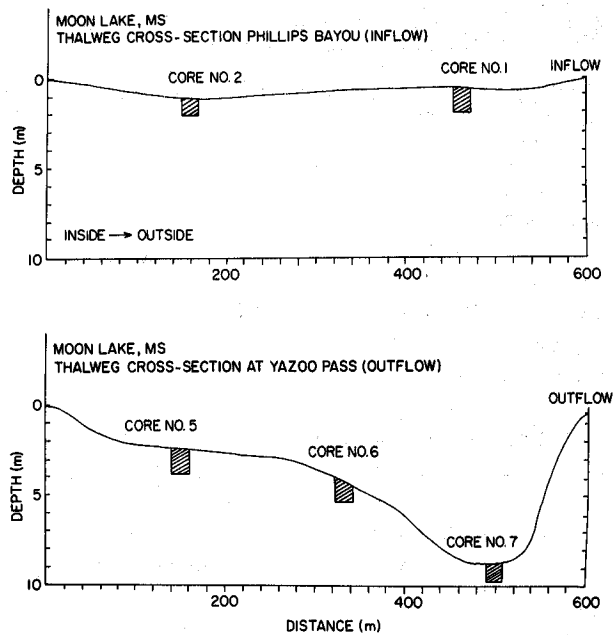


Figure 2. Moon Lake typical cross section.

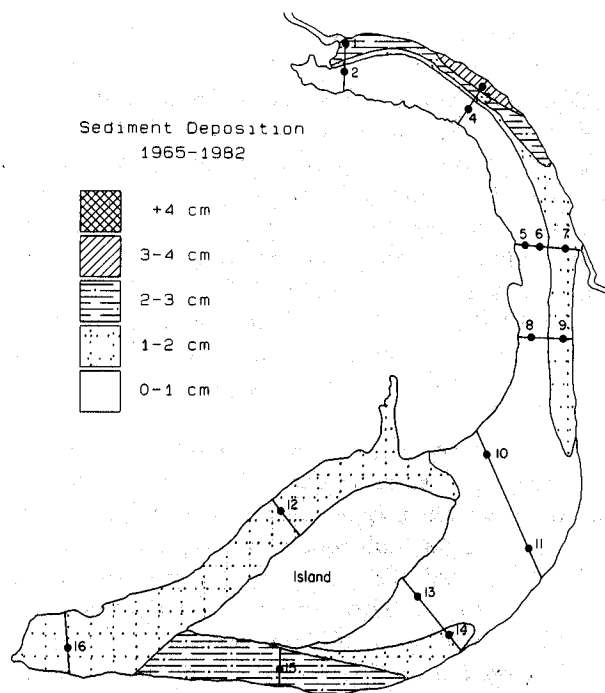


Figure 4. Sediment accumulation patterns per year in Moon Lake from 1965 through 1982 (with sampling sites).

4) were sampled in August 1982 using a plastic PVC corer (10-cm I.D.) fitted with a ball valve and metal pipe extensions. The sediment profile cores, 20 to 100+ cm in length, were sectioned into 10-cm increments and like increments were composited from eight cores per site. The composited samples were taken to the laboratory, air dried, passed through a screen with 0.6-cm openings, and dried at 105°C for

48 h. Samples (1000 g) were placed in Marinelli counting beakers and the concentration of  $^{137}\text{Cs}$  was measured by gamma-ray spectrometric analysis using a Ge-Li crystal and a 4096-channel spectrometer (Ritchie and McHenry 1973). Concentration of  $^{137}\text{Cs}$  was expressed in becquerels per gram (Bq/g). Previous research (Ritchie, McHenry, and Gill 1973; Pennington and others 1976) has shown that  $^{137}\text{Cs}$  accumulation can be used successfully to estimate recent sediment accumulation in water bodies for which no historical records exist. Concentrations of  $^{137}\text{Cs}$  first appeared in sediment profiles in 1954, the year significant atmosphere nuclear testing began and peaked in 1963 when radioactive fallout was maximum. Thus, estimates of sediment accumulation can be made from 1954 to the present. For calculation procedures, a threshold value of 0.74 Bq/g was defined as a positive identification of the first introduction of  $^{137}\text{Cs}$  in 1954. The 1963 peak concentration was assumed to occur in the middle of the 10 cm increment in which it was located. Particle size analysis—for the upper 10 cm and the entire core was determined by Sedigraph, a commercial particle size analyzer (Use of company names are provided for the reader only and do not imply endorsement or preferential use by the United States Department of Agriculture). Both the  $^{137}\text{Cs}$  and sediment analyses were conducted at the USDA-ARS Water Quality and Watershed Research Laboratory, Durant, Oklahoma. Contour lines for Figures 3 and 4 were approximated with the aid of a current contour map, knowledge of lake currents, and notes from numerous qualitative cores which were taken to help define sediment accumulation patterns.

## Results and Discussion

### Sedimentation Rates

Concentrations of  $^{137}\text{Cs}$  in sediment samples ranged from nondetectable to 9.6 Bq/g. These levels were consistent with concentrations found in other natural lakes in the lower Mississippi River Valley (Ritchie and others 1979) and for the United States (Hardy 1978; Ritchie and McHenry 1977). Temporal sedimentation patterns showed a substantial reduction in accumulated sediments during the period from 1965 through 1982 as compared with the period 1954 through 1964.

Rates of sedimentation (Table 1) in Moon Lake between 1954 and 1964 varied from 0.3 to 4.3 cm/yr with a mean of 2.6 cm/yr and a standard error of  $\pm 0.24$  cm/yr. Accumulation rates from 1964 through 1982 ranged from 0.3 to 3.4 with a mean of 1.2 cm/yr and a standard error of  $\pm 0.22$  cm/yr.

Spatial sedimentation patterns in Moon Lake varied

Table 1. Recent sedimentation rates in Moon Lake, Mississippi.

Site no.	Max. conc. depth (cm)	Max. sample depth (cm)	Deposition rate (cm/yr)	
			1954–1964	1965–1982
1	30–40	80+	4.3	1.8
2	10–20	30 <sup>a</sup>	2.5	0.7
3	60–70	100+	3.4	3.4
4	10–20	30 <sup>a</sup>	2.5	0.7
5	10–20	40 <sup>a</sup>	2.5	0.7
6	0–10	40	3.0	0.5
7	30–40	60	2.2	1.8
8	10–20	50	3.2	0.4
9	40–50	70	2.2	1.5
10	0–10	10	0.3	0.3
11	0–10	30	2.0	0.3
12	30–40	60 <sup>a</sup>	2.5	1.8
13	0–10	20	1.2	0.7
14	20–30	60 <sup>a</sup>	3.4	1.2
15	40–50	80	3.4	2.4
16	10–20	50	3.1	1.2

<sup>a</sup>Deepest sample not below depth of Cs-137 burial.

with (1) proximity to inflow and outflow, (2) water residence time, and (3) location in respect to effective wind fetch. Deposition was greatest in the upper end of the lake (Fig. 3) near the major inflow. Other minor inflows also created small areas of deposition. Deposition that accompanied the major flow pattern from inflow to outflow was evident (Fig. 4) even during periods of little sedimentation. The extreme southern end of the lake experienced higher sedimentation rates than the main body of Moon Lake between the island and the outflow (Figs. 3, 4). This southern portion of the lake experiences less wind action since prevailing winds are blocked by the mainline Mississippi River levee. The inflow-outflow relationship in Moon Lake is also such that sediment-laden water in the southern end of the lake has an extended residence time. The isolating nature of the island also influences wind action and water residence time. These factors allow for a more complete settling of particles from the water column.

Seventy percent of the lake experienced sedimentation rates that averaged greater than 2 cm/yr from 1954 through 1964 (Table 2). By comparison, 86 percent of the lake had accumulation rates that averaged less than 2 cm/yr during the period 1965 through 1982. A paired observation t-test indicated a significant difference ( $\alpha = 0.01$ ) between accumulation rates for the two periods. This reduction in the rate of sediment deposition that reflects the total sediment load delivered from an intensively cultivated watershed, also indicates a major shift in agricultural practices and economy during the 1960s and 1970s.

Table 2. Sediment accumulation rates in Moon Lake, Mississippi.<sup>a</sup>

Deposition rate (cm/yr)	Km <sup>2</sup> (%) 1954–1964	Km <sup>2</sup> (%) 1965–1982
0–1	1.4 (15%)	5.0 (54%)
1–2	1.4 (15%)	3.1 (32%)
2–3	4.8 (51%)	1.2 (13%)
3–4	1.5 (16%)	0.1 (1%)
4+	0.3 (3%)	0.0

<sup>a</sup>Rates calculated by area of bottom and percentage of total area (in parenthesis).

In 1954 cotton was the dominant crop in Tunica County, Mississippi (R. N. Jones, Area Conservationist, SCS, Pers. Comm. 1986). Cotton requires early seed bed preparation, which results in bare, unprotected soil during the spring rainy season; it also requires intensive cultivation for weed control. By 1972, cotton had declined to the third major crop behind soybeans and rice. Conventionally tilled soybeans require less cultivation than cotton, and many farmers changed to reduced tillage systems and double-cropped with winter wheat. Both the 2-crop system and reduced fuel costs became more attractive to farmers in the 1960s and 1970s. Rice requires no cultivation after seed bed preparation. Thus, the cropping system changes experienced in the Moon Lake watershed in the last two decades have resulted in a substantial reduction of sediment deposition in Moon Lake.

#### Sediment Particle-size Distribution

Sediment profile contents for less than 0.002 mm clay percentages are plotted in Figure 5 as a function of the distance from inflow. The percentage of fine clay (<2  $\mu$ m) in the 0 to 10 cm layer was only slightly greater than in the total sample for most sites. It also increased with distance from inflow with the exception of sites near tributary inflows. While the rate of sediment production has varied over the past three decades, the products of erosion, as determined by particle size distribution, have been of similar quality.

#### Predicted Changes in Moon Lake

Deposition patterns and rates over the past three decades allow general prediction of future trends. Since the two shallow ends (<1 m) of the oxbow (Fig. 4) have the greatest rates of deposition, they will visibly change most rapidly. Wind action and poor light penetration (Cooper and others 1984) will restrict secondary succession to hardy emergent species for several years, but as sediments continue to accumulate, encroaching woody shrubs and trees will continue to extend into the lake. Fluctuations in water level will

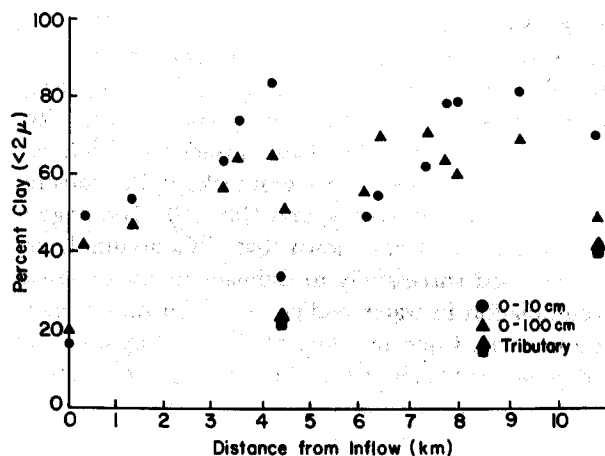


Figure 5. Percent clay finer than 2  $\mu$ m in bottom sediments of Moon Lake as a function of distance from inflow.

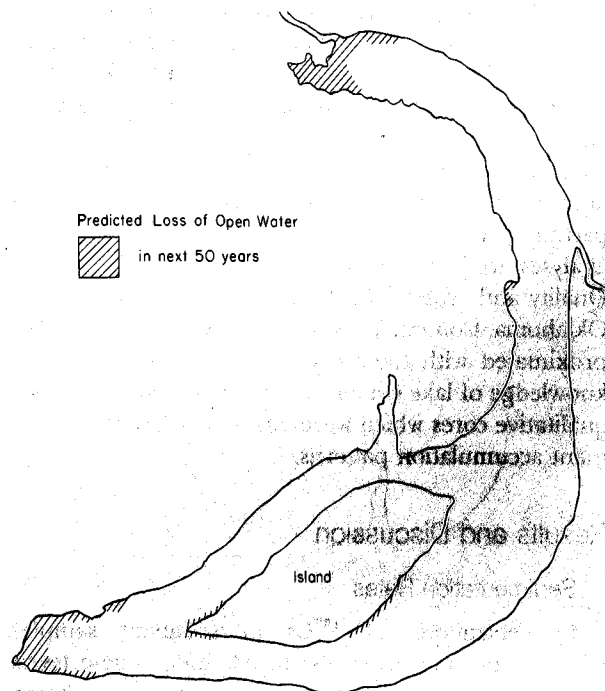


Figure 6. Predicted loss of open water habitat in Moon Lake during the next 50 years.

also favor woody species. Eutrophication, which is currently not a problem, would improve growth conditions for emergent and floating herbaceous species.

If current deposition rates continue, the shallow ends of the oxbow and adjoining littoral zones are the only parts of Moon Lake that will noticeably fill during the next 50 years (Fig. 6). Deposition may reduce open water habitat by 0.4 to 0.8 km<sup>2</sup> or 3 to 7 percent during this period. Current accumulation rates are

substantially less than those found in many relic oxbows of the Yazoo River where rates may exceed 7 cm/yr (Ritchie and others 1977). If accumulation rates continue to decline, water quality of the lake will improve and a few noticeable changes should occur in the next 50 years. Conversely, if land use practices revert to more intensive cultivation and increase inflowing sediments, alteration of shallow open water areas to wetlands will accelerate and water quality and aquatic productivity will decline.

### Summary

A study of recent sediment accumulation rates and patterns in Moon Lake documented that changes in agricultural practices since 1965 have reduced sedimentation rates by 50 percent as compared with the period 1954 to 1964. Major spatial sediment accumulation patterns in the area included inflow to outflow circulation pattern and slack water regions. Current rates of deposition will convert 3 to 7 percent of the open water habitat to wetland during the next 50 years.

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